Open X-ray tomography data and code from the Helsinki lab

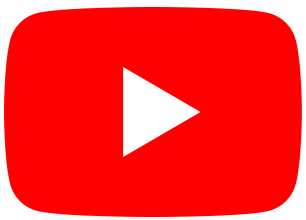
Samuli Siltanen

Numerical methods for Computed Tomography:
Scientific innovations & industrial challenges

Bologna, Italy

January 26, 2023

Instagram:
@samuntiede
@monday_spider



YouTube:
@professor_sam
@Samuntiedekanava

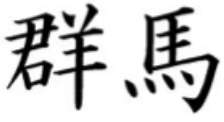
This my industrial-academic background

2009: Professor, University of Helsinki, Finland

2006: Professor, Tampere University of Technology, Finland

2005: R&D scientist at Palodex Group

2004: R&D scientist at GE Healthcare

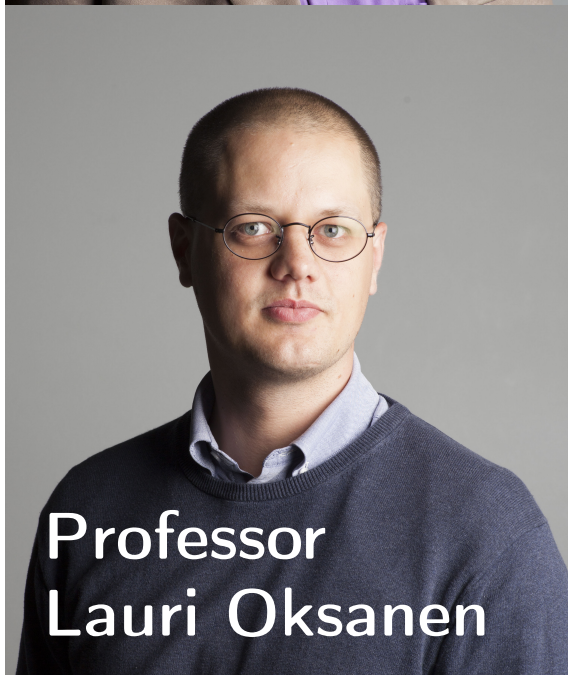


2002: Postdoc at Gunma University, Japan

2000: R&D scientist at Instrumentarium Imaging

1999: PhD, Helsinki University of Technology, Finland

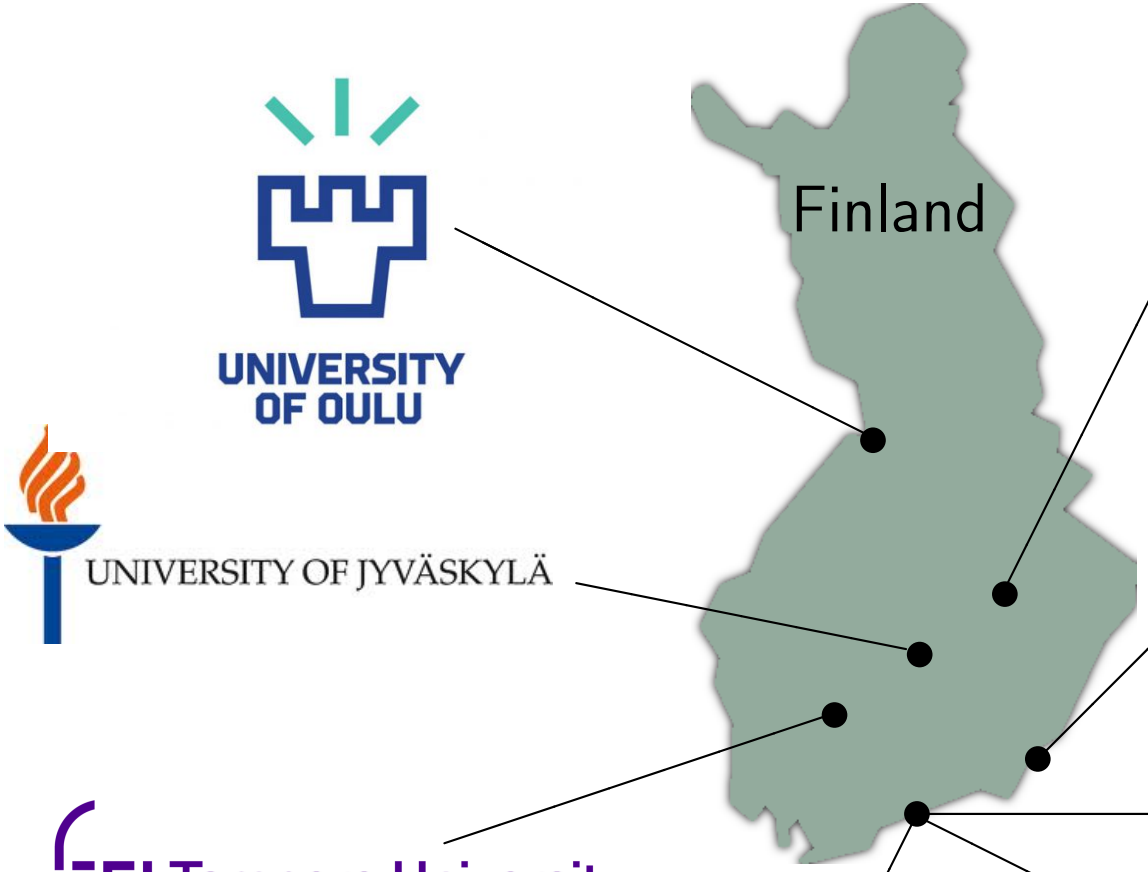
We have a research group of roughly 30 people at University of Helsinki



Finnish Centre of Excellence in Inverse Modelling and Imaging

2018-2025

CENTRES OF EXCELLENCE IN RESEARCH



UNIVERSITY OF OULU

UNIVERSITY OF EASTERN FINLAND

LUT University

UNIVERSITY OF JYVÄSKYLÄ

UNIVERSITY OF HELSINKI

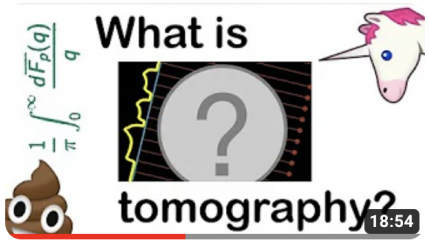
Tampere University

FINNISH METEOROLOGICAL INSTITUTE

Aalto University

Samun tiedekanava

7 231 subscribers, 295 000 views, https://youtube.com/@Samuntiedekanava

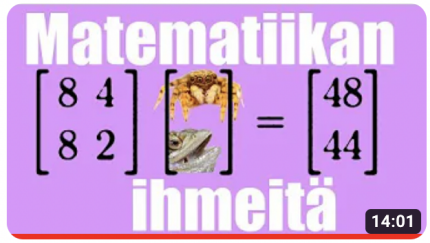


What is tomography?

23K views • 2 years ago

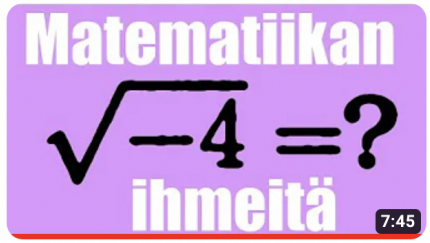
Mathematical modelling: How does a virus spread in a population?

21K views • 2 years ago



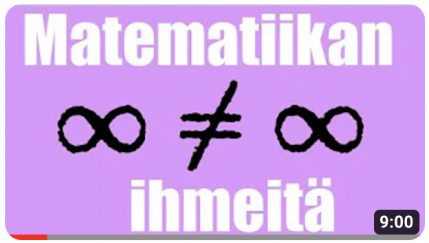
Wonders of Mathematics: Matrices

16K views • 3 years ago



Wonders of Mathematics: Complex numbers

11K views • 4 years ago



Wonders of mathematics: Infinity

11K views • 3 years ago

Sam's Science Splash: Fish Removal

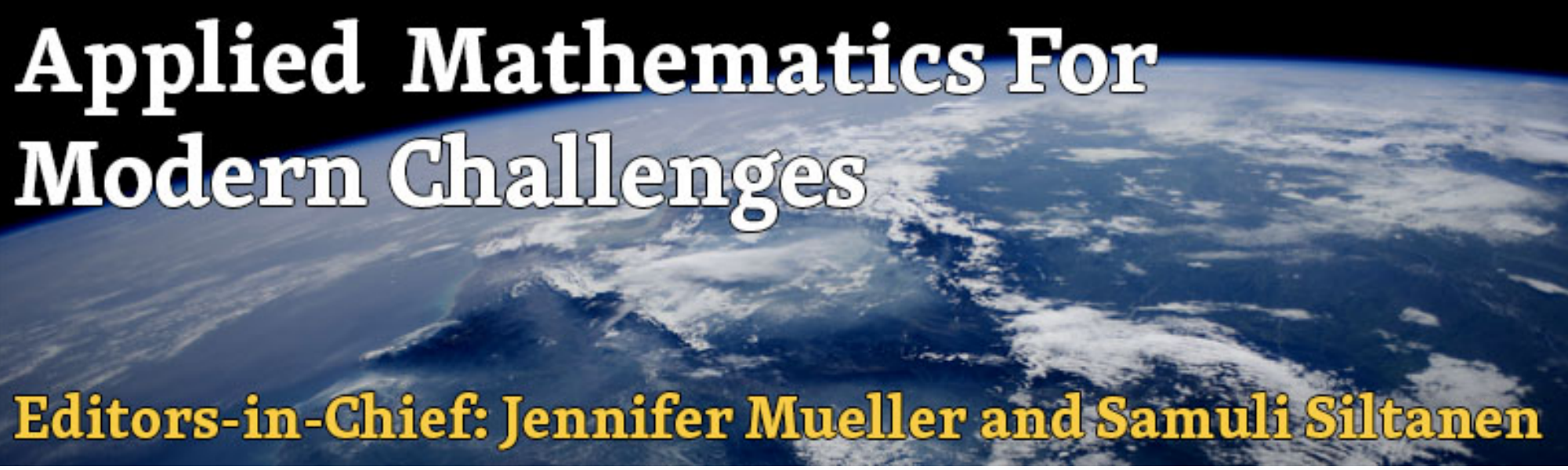
7.3K views • 5 years ago

Wonders of mathematics: Fourier series

6.8K views • 2 years ago

Samun tiedepläjäys: Nopanheitto ja todennäköisyyden luonne

6.4K views • 5 years ago

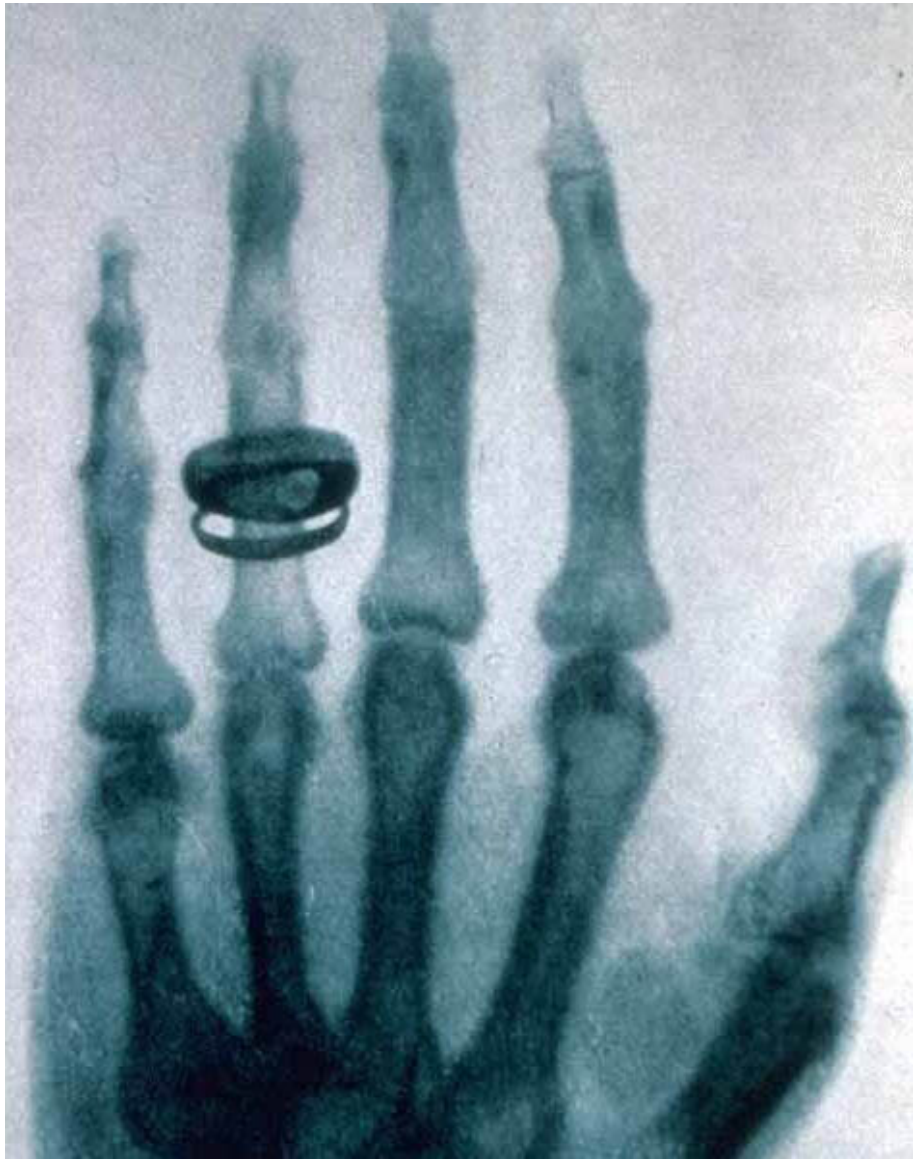


Announcing a new journal for real-world mathematics!

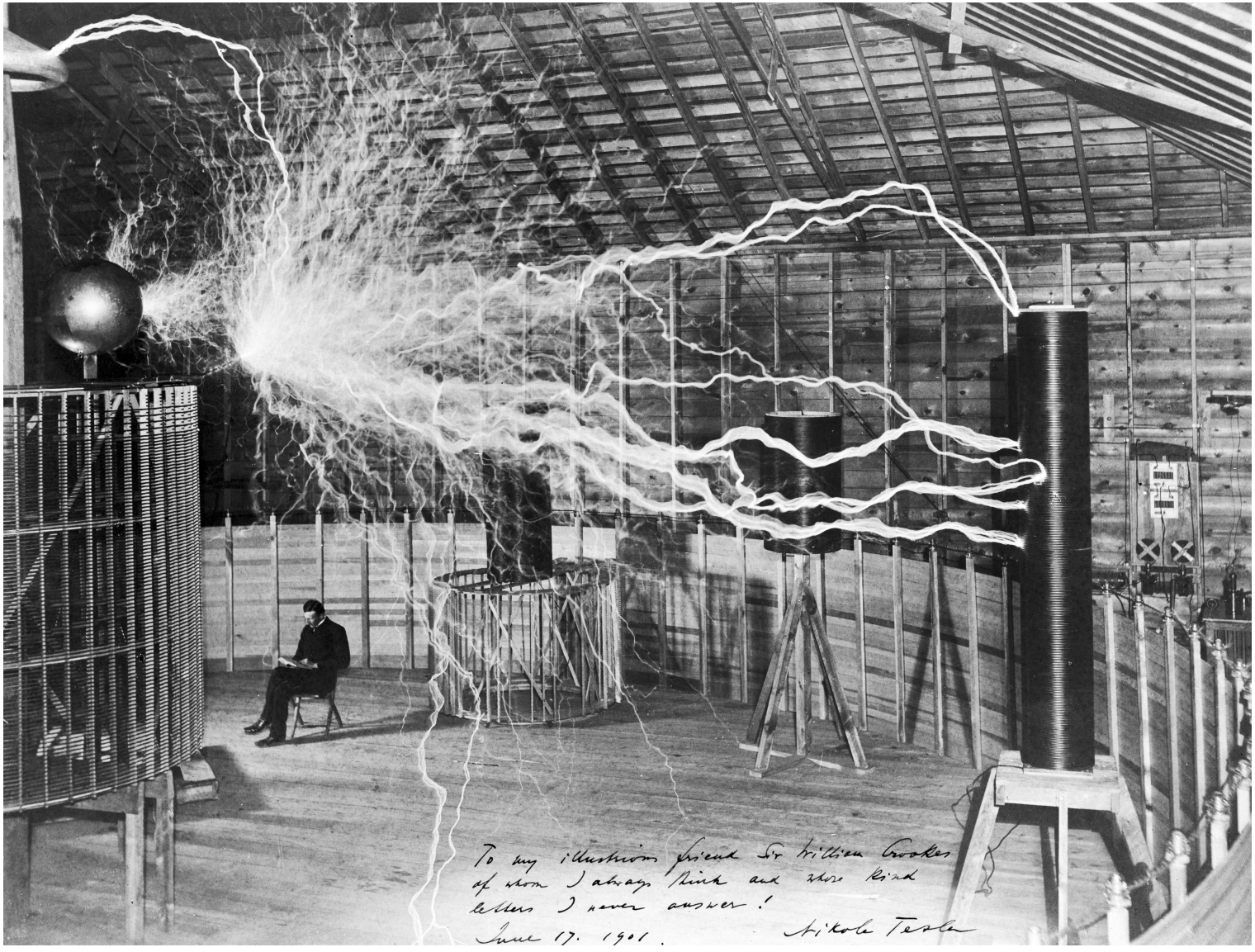
https://www.aimsciences.org/AMMC

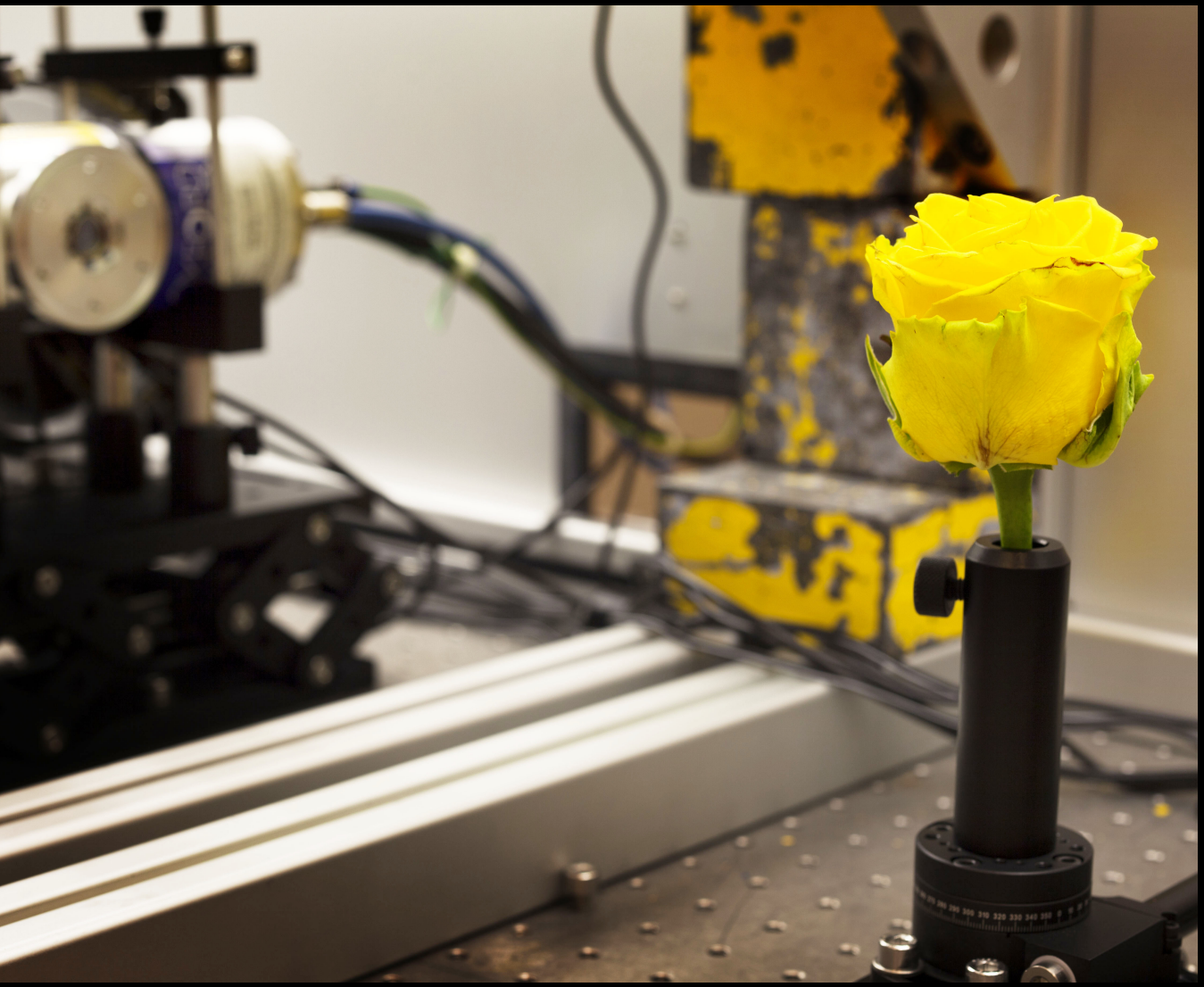
Outline

Wilhelm Conrad Röntgen invented X-rays and was awarded the first Nobel Prize in Physics in 1901



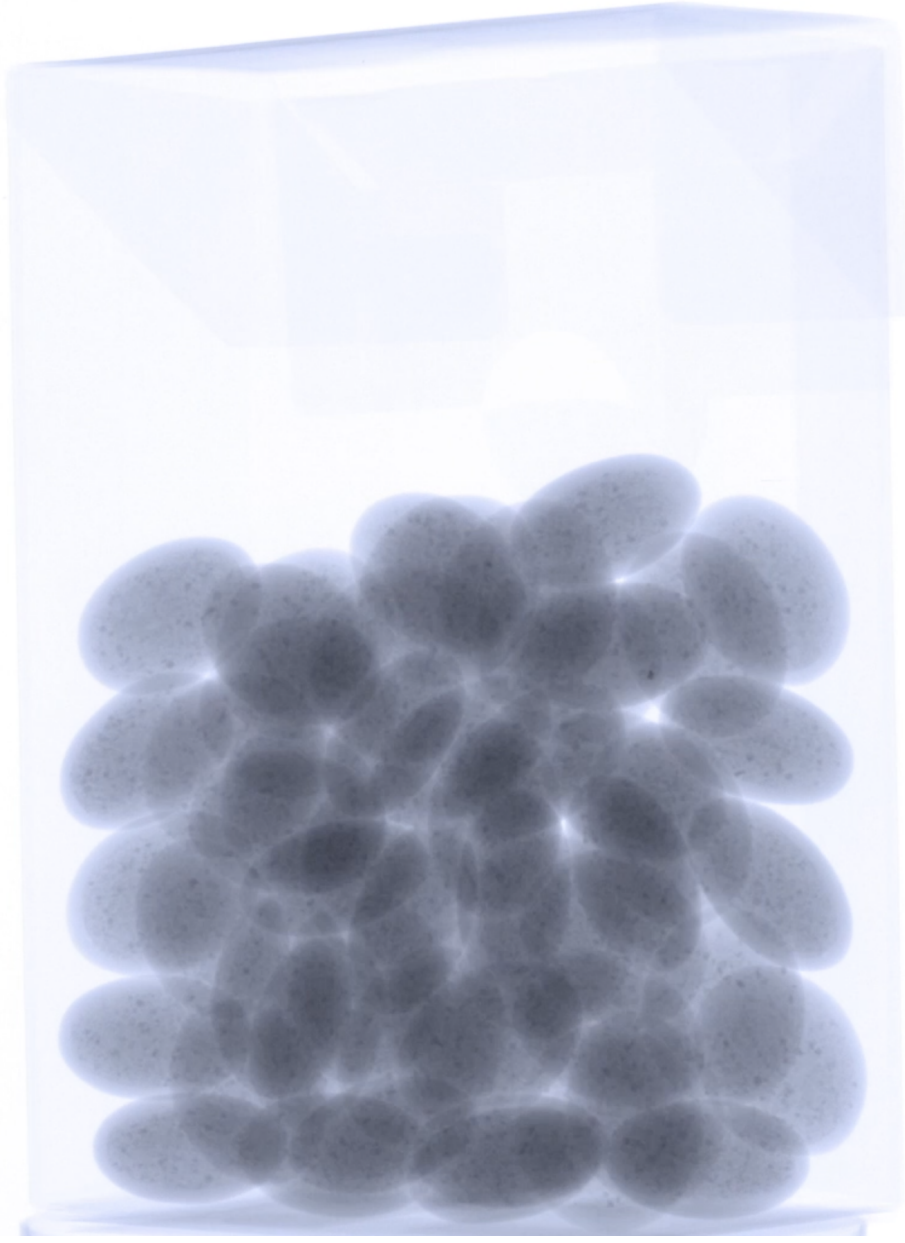
But even before Röntgen, Nikola Tesla had observed X-rays in his own way






HAMAMATSU
DIGITAL OUT
EXT TRG
POWER

We can see through a box of candy!



Outline

Static X-ray datasets from the Helsinki lab

There are many datasets on this page:
https://fips.fi/dataset.php

Outline

We construct a dynamic “emoji phantom” using small stones and stop-motion animation

Measurement:
Zenith Purisha

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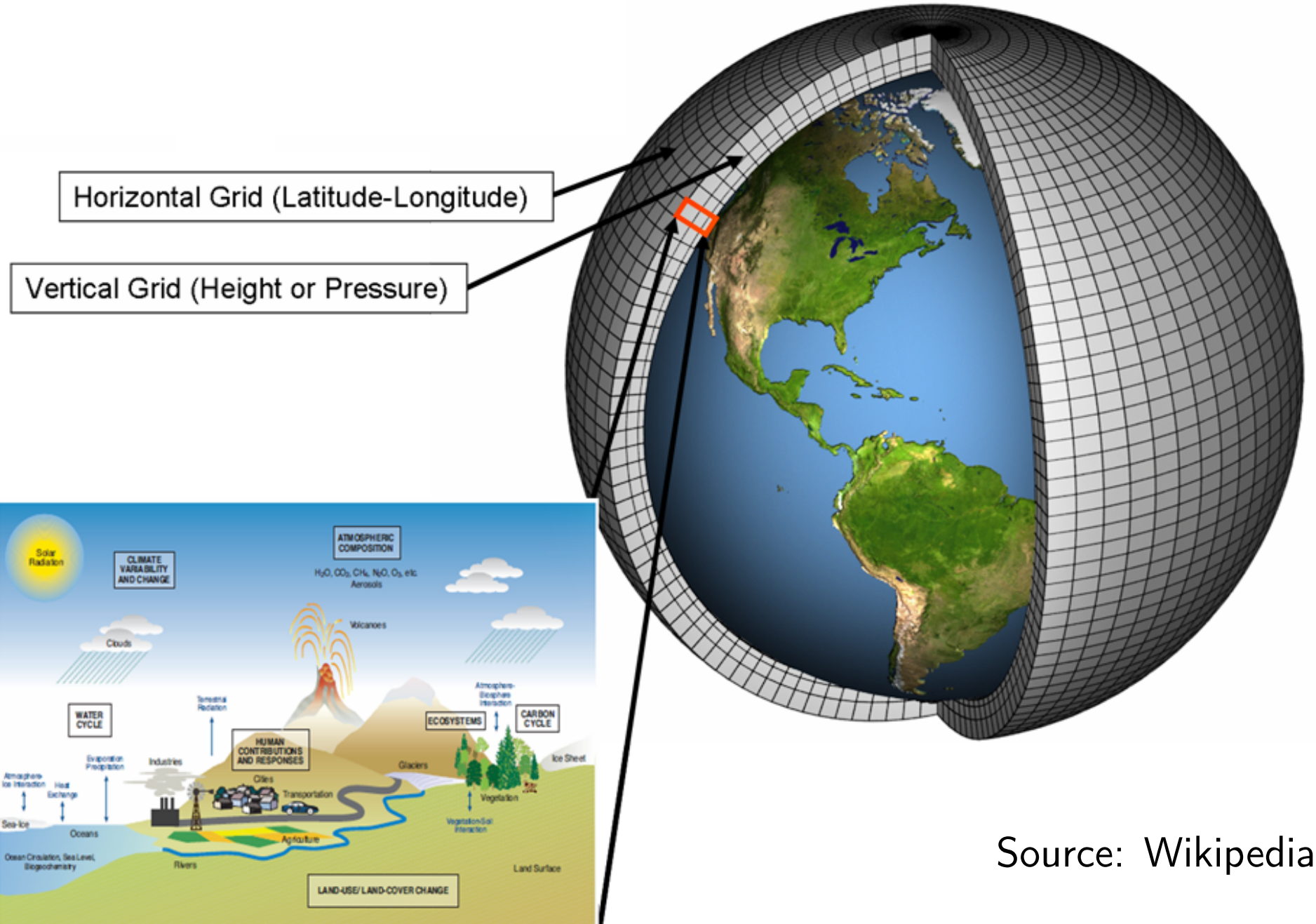
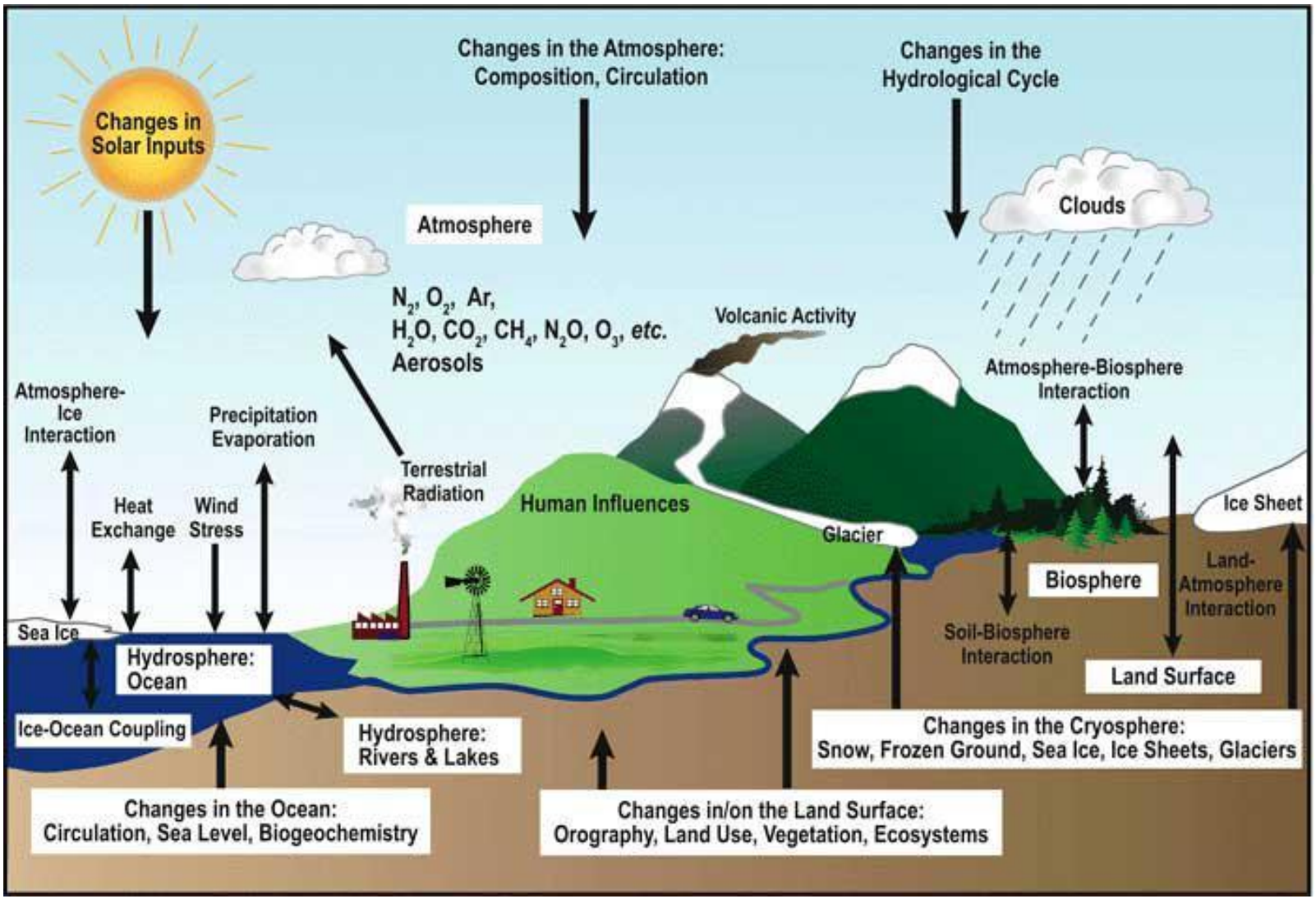
Plant metabolism dynamic phantom

Climate change is predicted using climate models



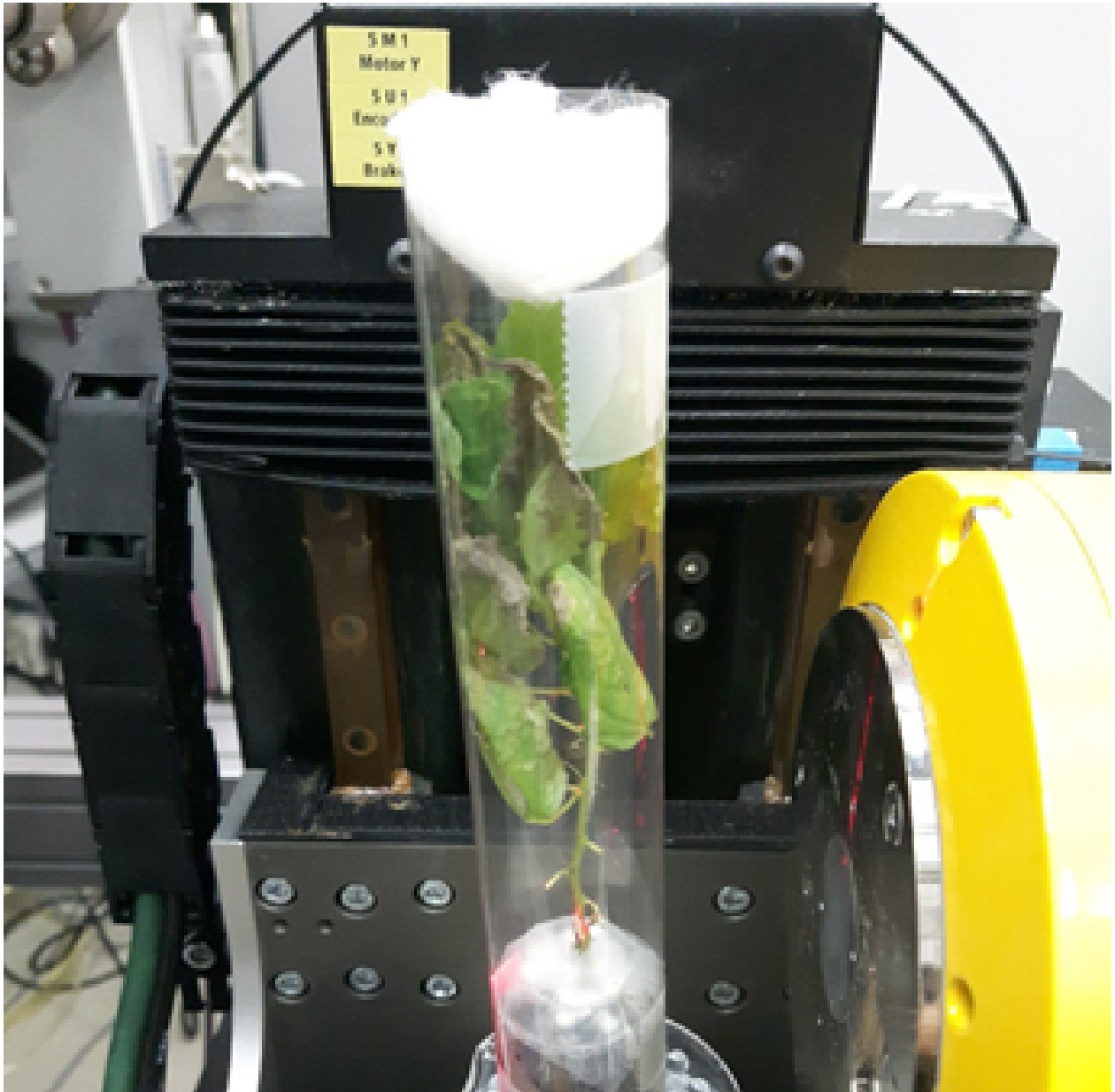
Source: Wikipedia

Climeta models have a lot of details, and plant metabolism is crucial to model accurately



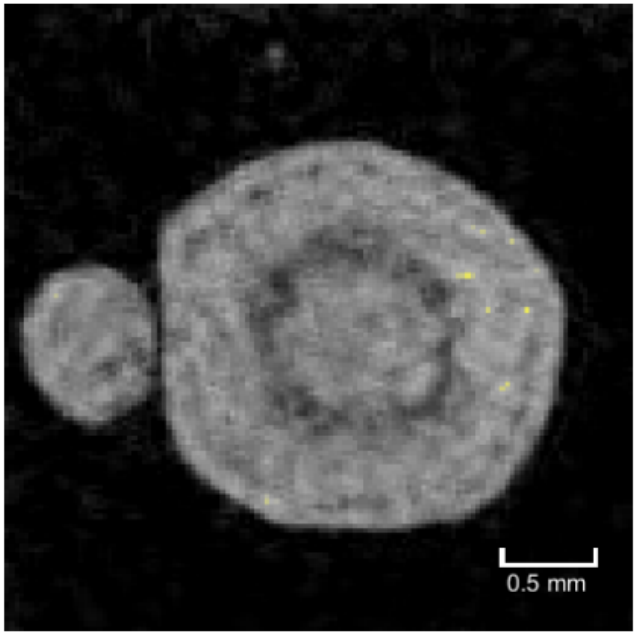
Le Treut, Somerville, Cubasch, Ding, Mauritzen, Mokssit, Peterson & Prather 2007

Tomography study jointly with physicists, biologists, radiochemists and climate scientists

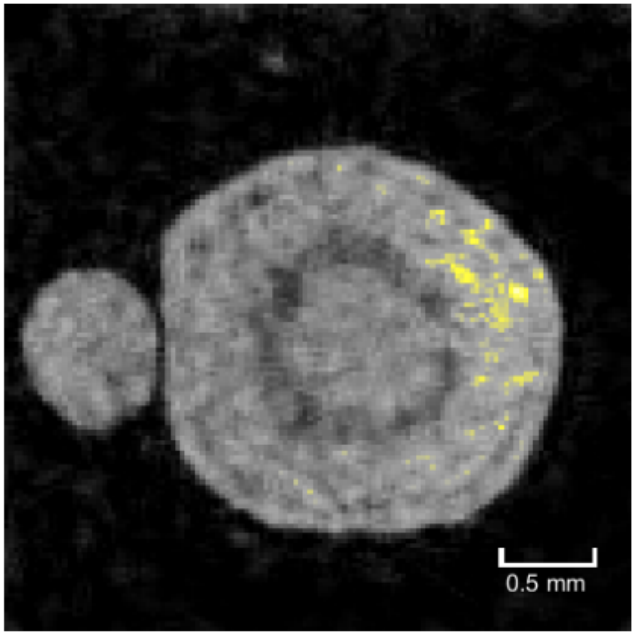


Time-dependent sparse tomography reveals the movement of iodine in the phloem

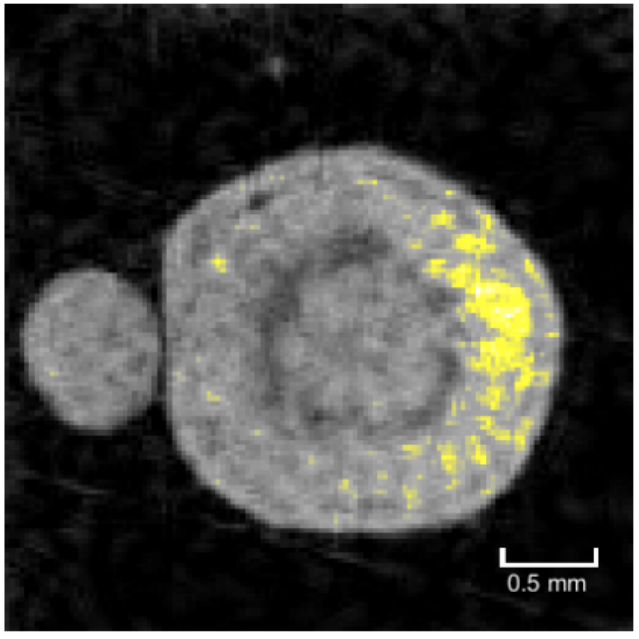
0 minutes



166 minutes



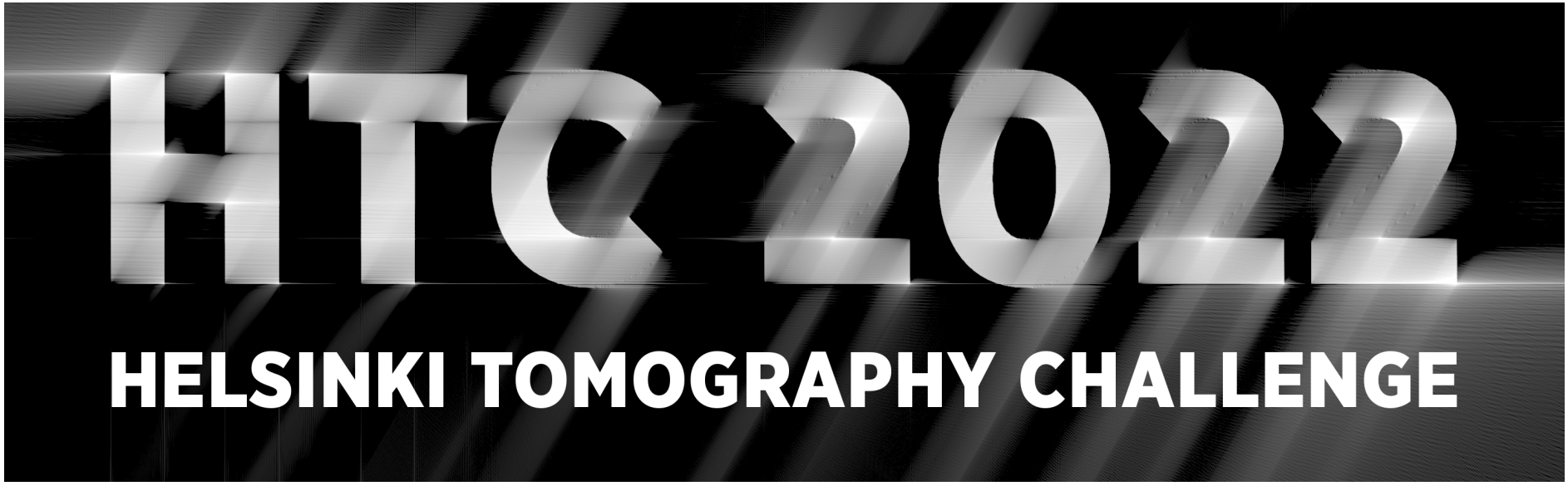
235 minutes



Bubba, Heikkilä, Help, Huotari, Salmon & S, in press

Motorized phantom by Tommi Heikkilä

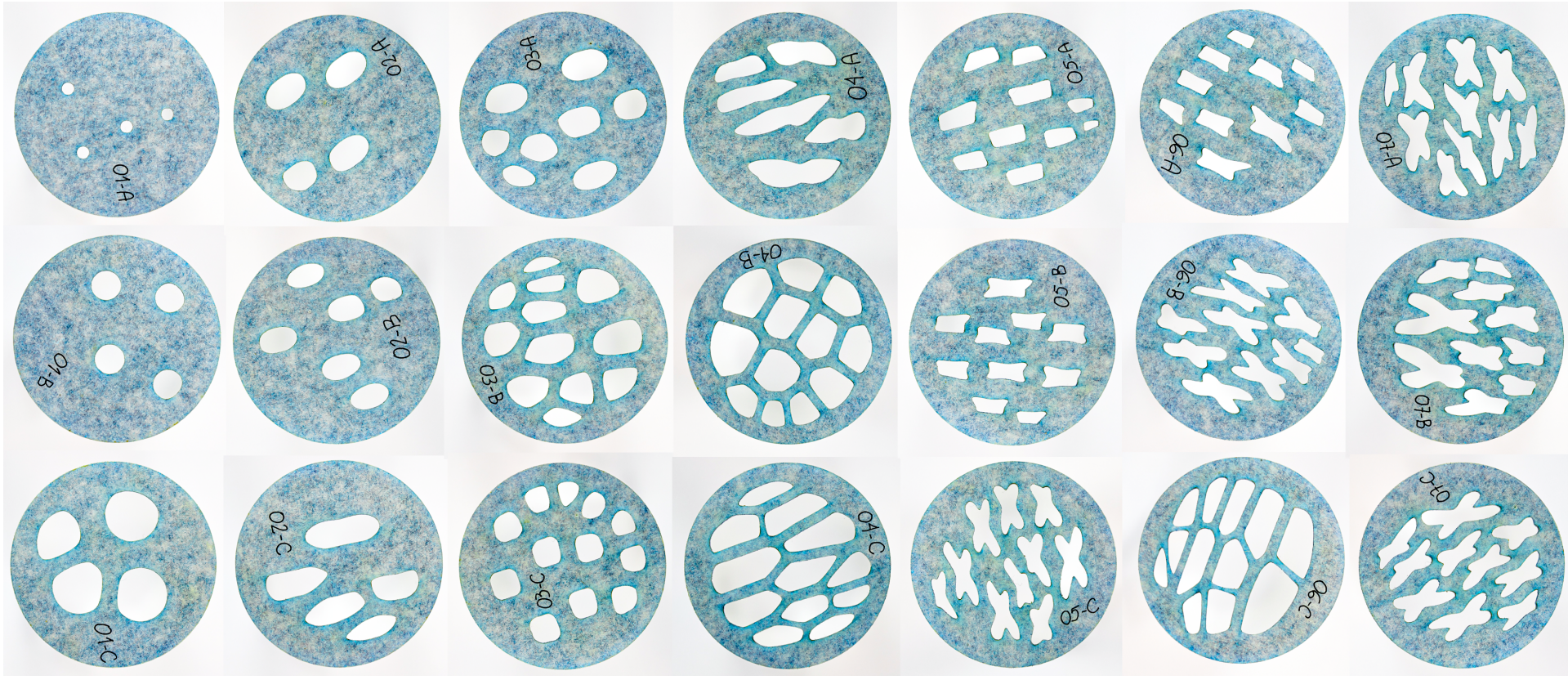
Outline



Check it out: https://www.fips.fi/HTC2022.php

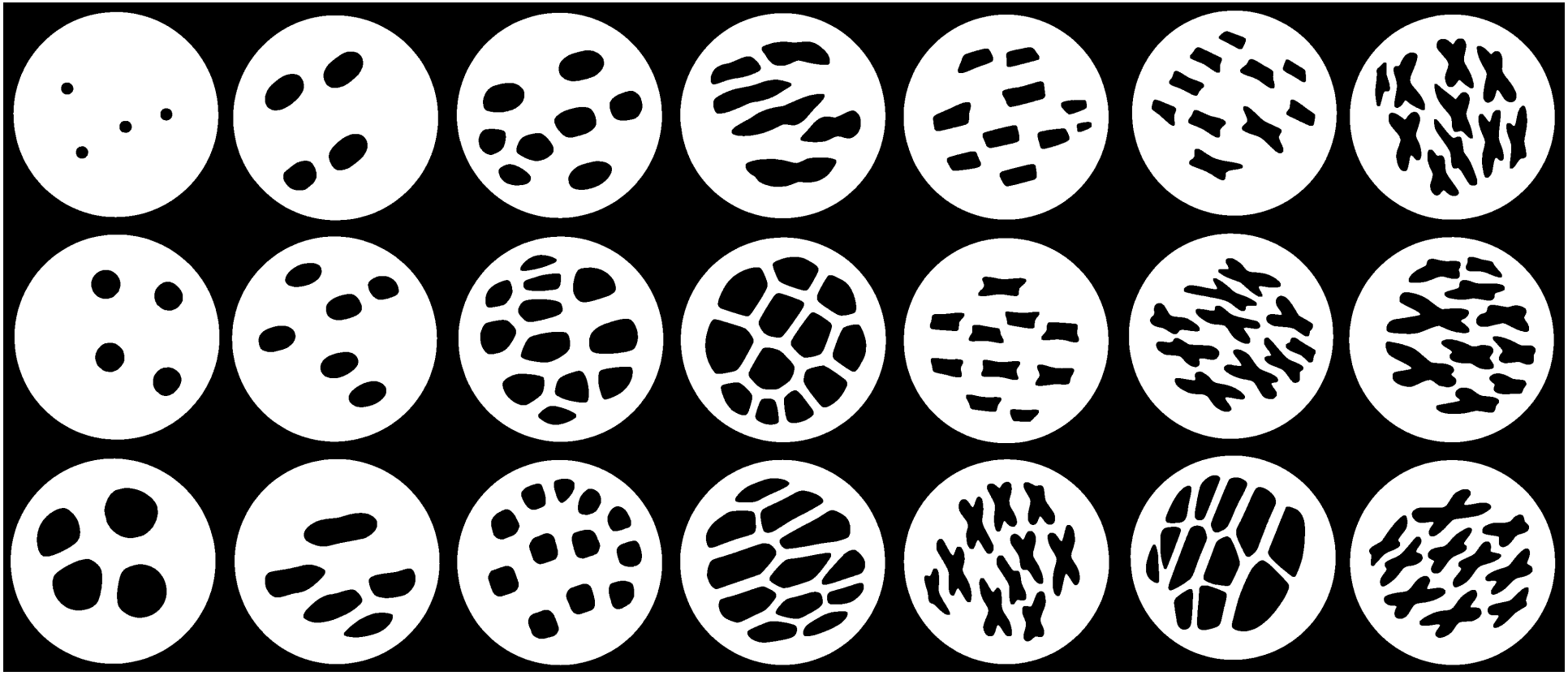
Challenge production team: Alexander Meaney, Fernando Moura, Siiri Rautio, Salla Latva-Äijö, Tommi Heikkilä and S.

We made several plastic phantoms with differently shaped holes in them



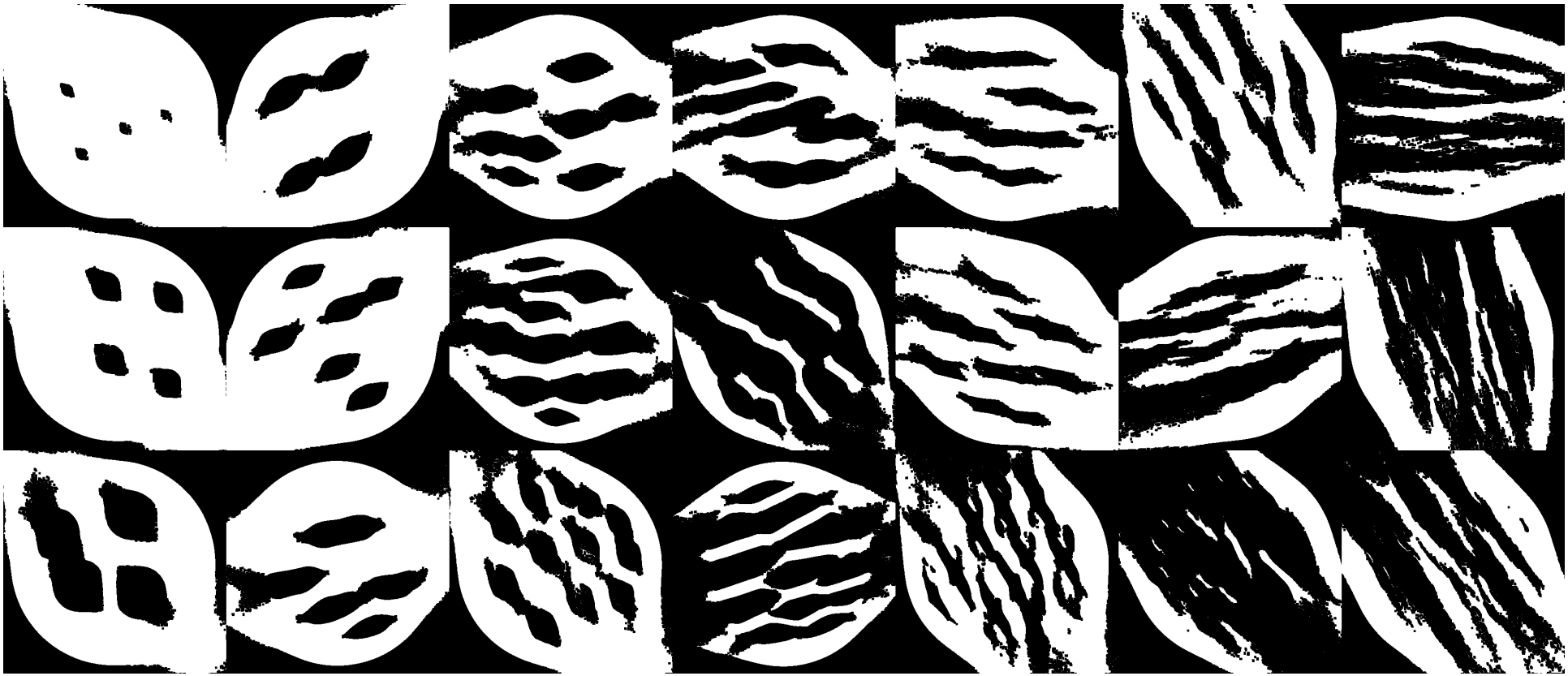
Shown are segmented FBP reconstructions from full-angle data

We measured full-angle X-ray data of the discs using our lab in Helsinki



Shown are segmented FBP reconstructions from full-angle data

The difficulty of reconstruction was raised by limiting the angle of view step by step

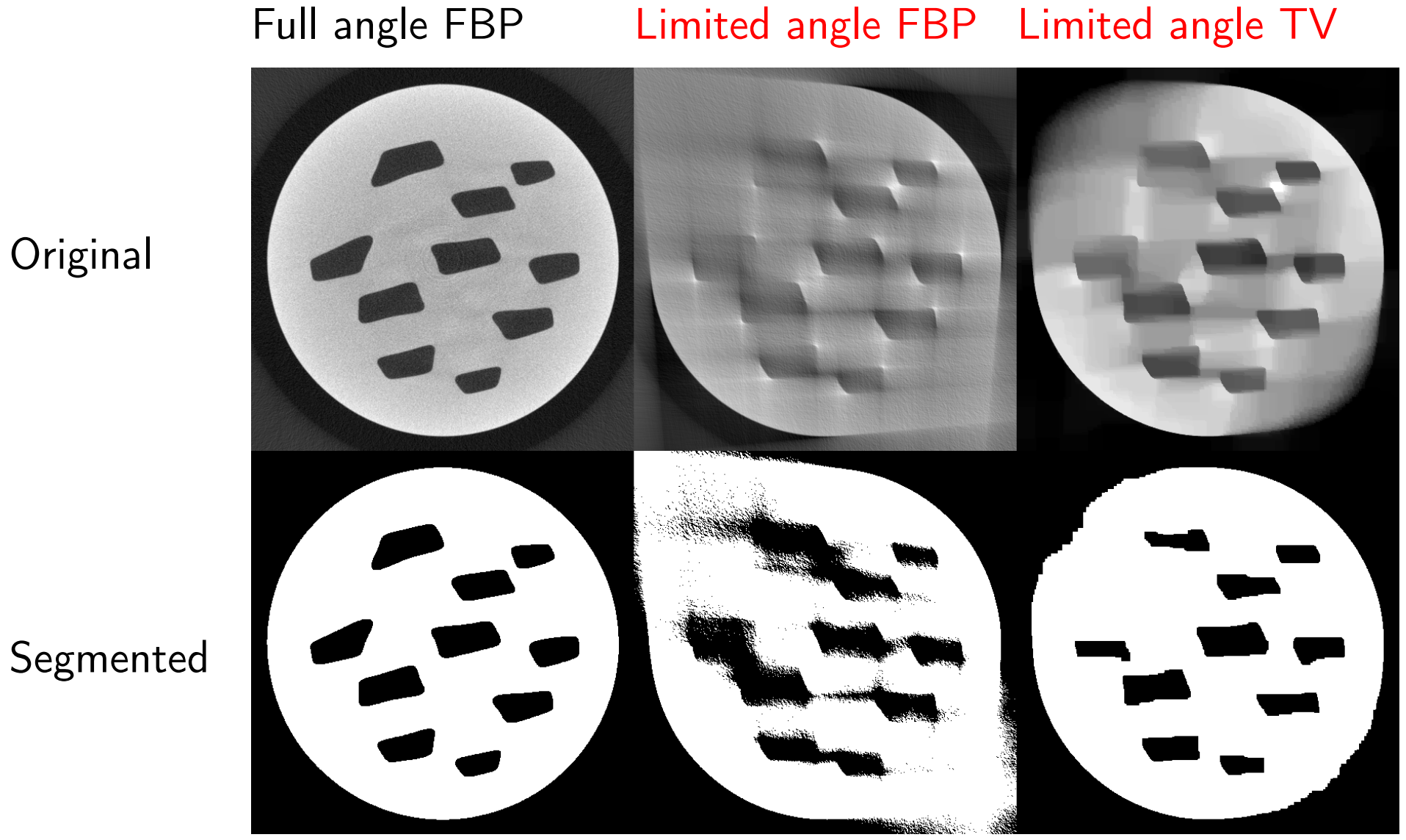


Shown are segmented FBP reconstructions from limited-angle data.
Angular ranges were $90^\circ \rightarrow 80^\circ \rightarrow \ldots \rightarrow 30^\circ$

Helsinki Tomography Challenge 2022: phantom difficulty groups

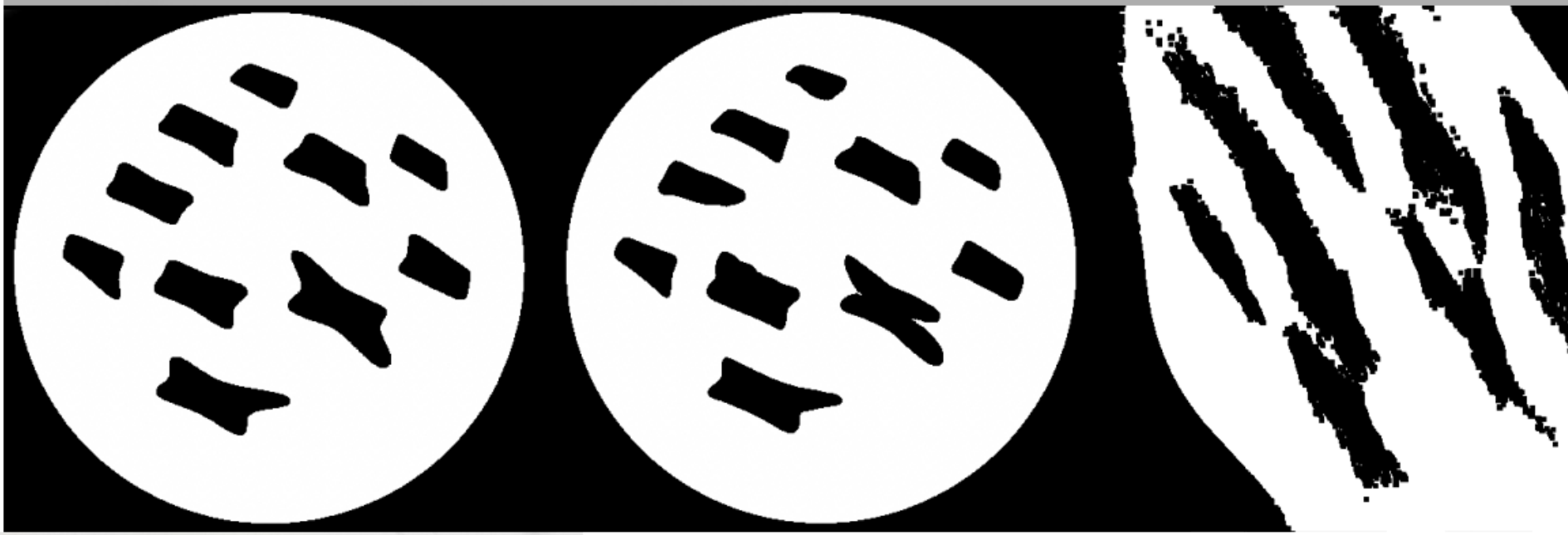
Group	Angular range	Angle increment	Number of projections
1	90°	0.5	181
2	80°	0.5	161
3	70°	0.5	141
4	60°	0.5	121
5	50°	0.5	101
6	40°	0.5	81
7	30°	0.5	61

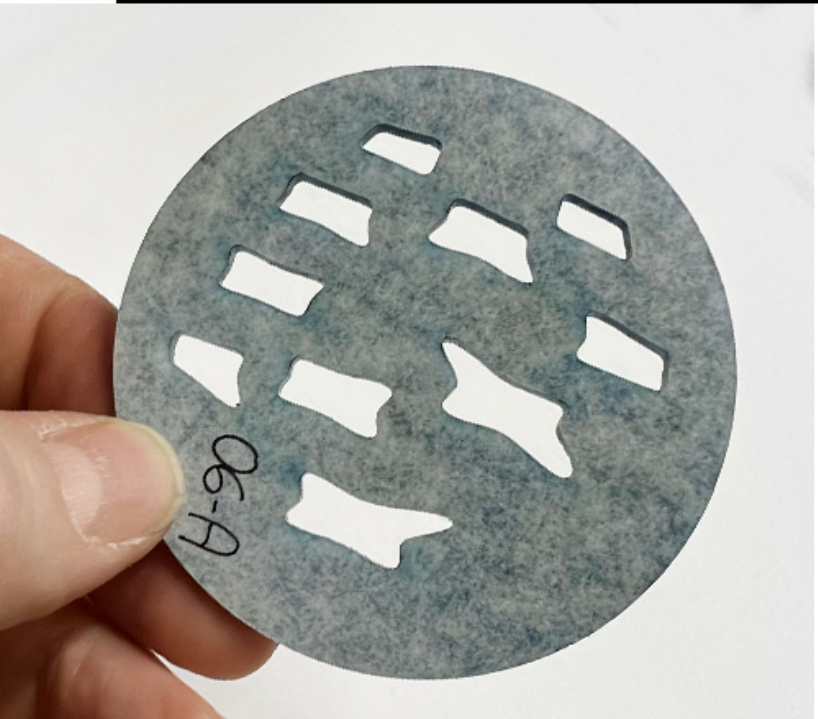
Limited angle tomography is difficult



See [Greenleaf & Uhlmann 1989], [Quinto 1993], and [Frikel & Quinto 2013]

Ground truth Winner FBP





The Helsinki Tomography Challenge 2022

9 particapting teams from **7** countries:

- Austria
- Brazil
- China
- Denmark
- Germany
- India
- Singapore

Altogether **22** different algorithms were submitted.

Scoring the quality of reconstructions

Reconstructed binary image is I_r, ground truth binary image is I_t. The score of the reconstruction is given by the Matthews correlation coefficient (MCC). Define

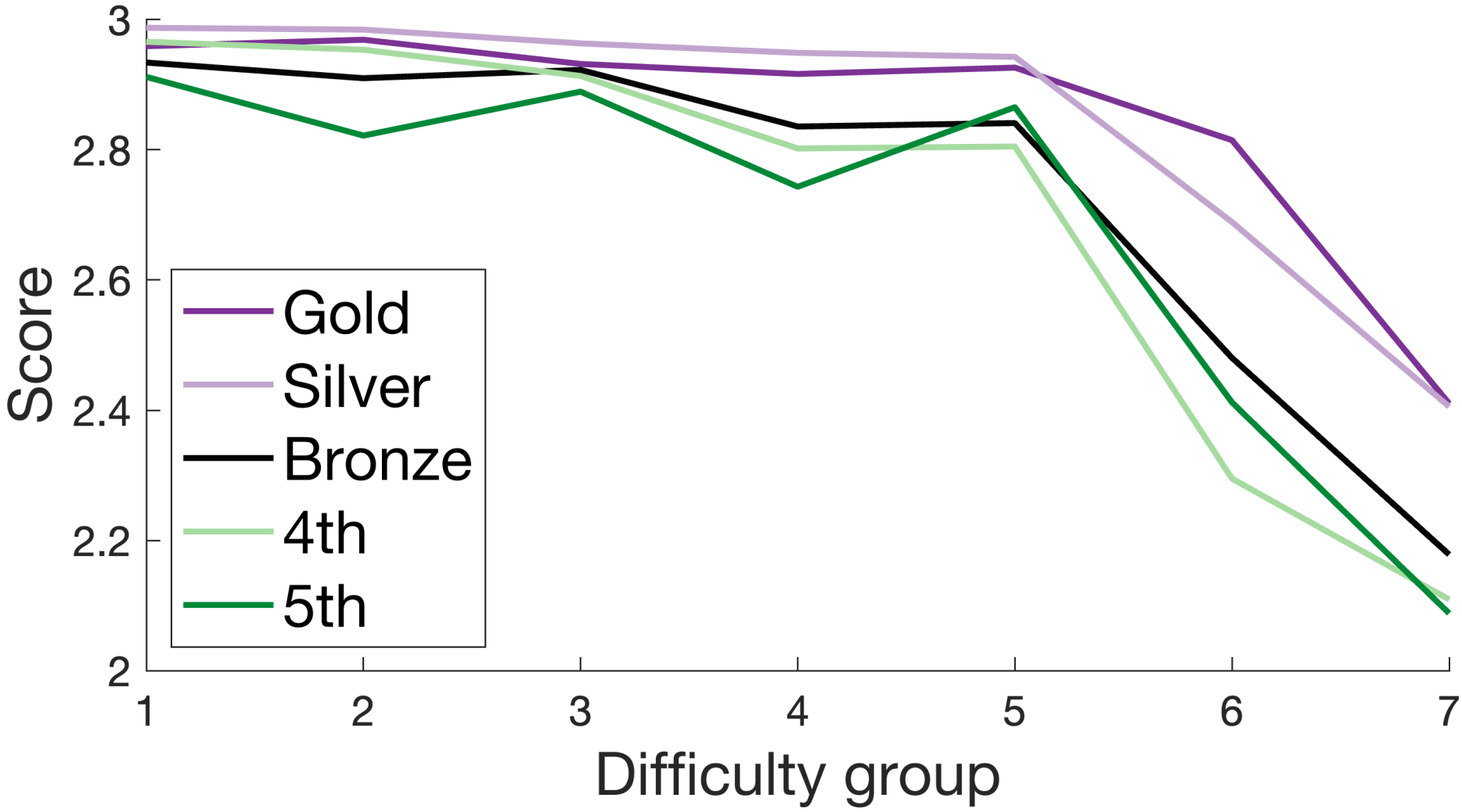
$$TP = \sum_{i,j} (I_t \cap I_r)_{ij}, \qquad FP = \sum_{i,j} (\bar{I}_t \cap I_r)_{ij},$$
$$FN = \sum_{i,j} (I_t \cap \bar{I}_r)_{ij}, \qquad TN = \sum_{i,j} (\bar{I}_t \cap \bar{I}_r)_{ij}.$$

Calculate MCC score $S \in [-1, 1]$ as

$$S = \frac{TP \times TN - FP \times FN}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}}.$$

A score of +1 (best) represents a perfect reconstruction, 0 no better than random reconstruction, and -1 (worst) indicates total disagreement between reconstruction and ground truth.

The scores of the five best teams in HTC2022



The Helsinki Tomography Challenge 2022

The top ranking teams are:

1. T Germer, J Robine, S Konietzny, S Harmeling and T Uelwer (TU Dortmund); H Heine (University Düsseldorf).
2. A Denker, C Arndt, J Nickel, J Leuschner, J Godeke, and S Dittmer from University of Bremen (ZeTeM).
3. G Fardell, J S Jorgensen, L Murgatroyd, E Papoutsellis, and E Pasca from DTU, Denmark.

The full results are viewable at
https://fips.fi/HTC2022_results.pdf.

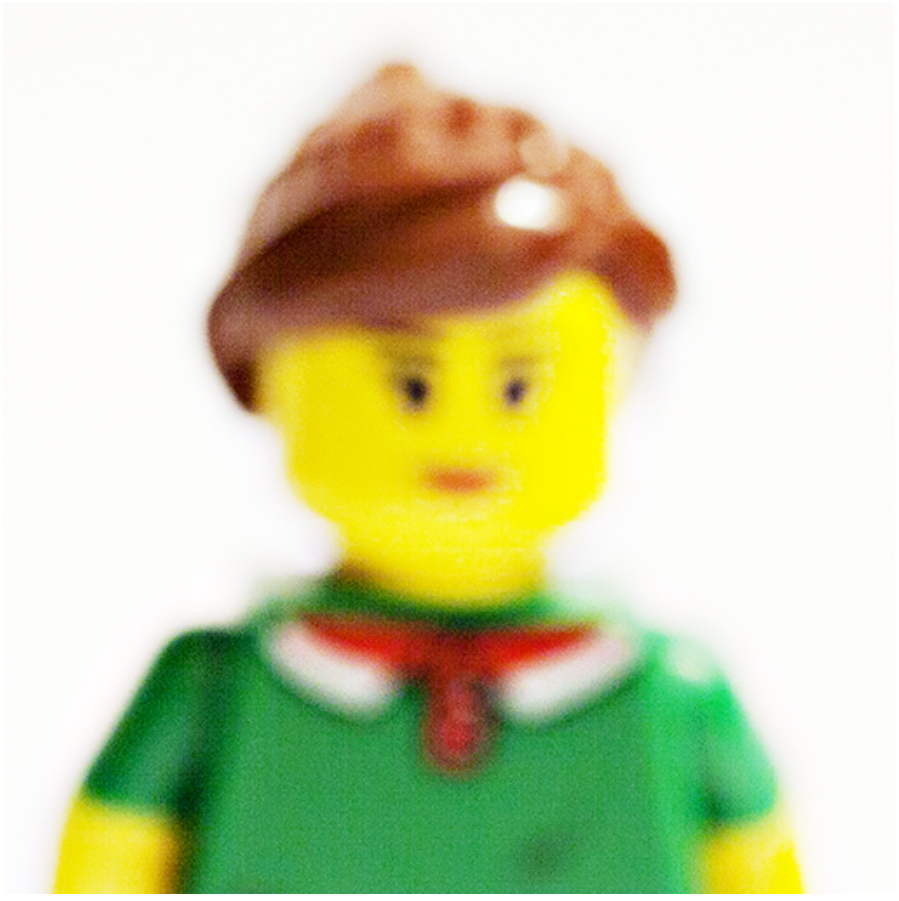
All the data and participating algorithms are openly available.

Outline

Joskus valokuvan tarkennus menee oikein

Joskus valokuvan tarkennus menee pieleen

Voimme kokeilla Photoshopin komentoa nimeltä *unsharp mask*



Tässä on toisen perusmenetelmän tulos

Uudenaikaisempiakin menetelmiä on, tässä kokonaisvaihtelutemppu (Total Variation, TV)

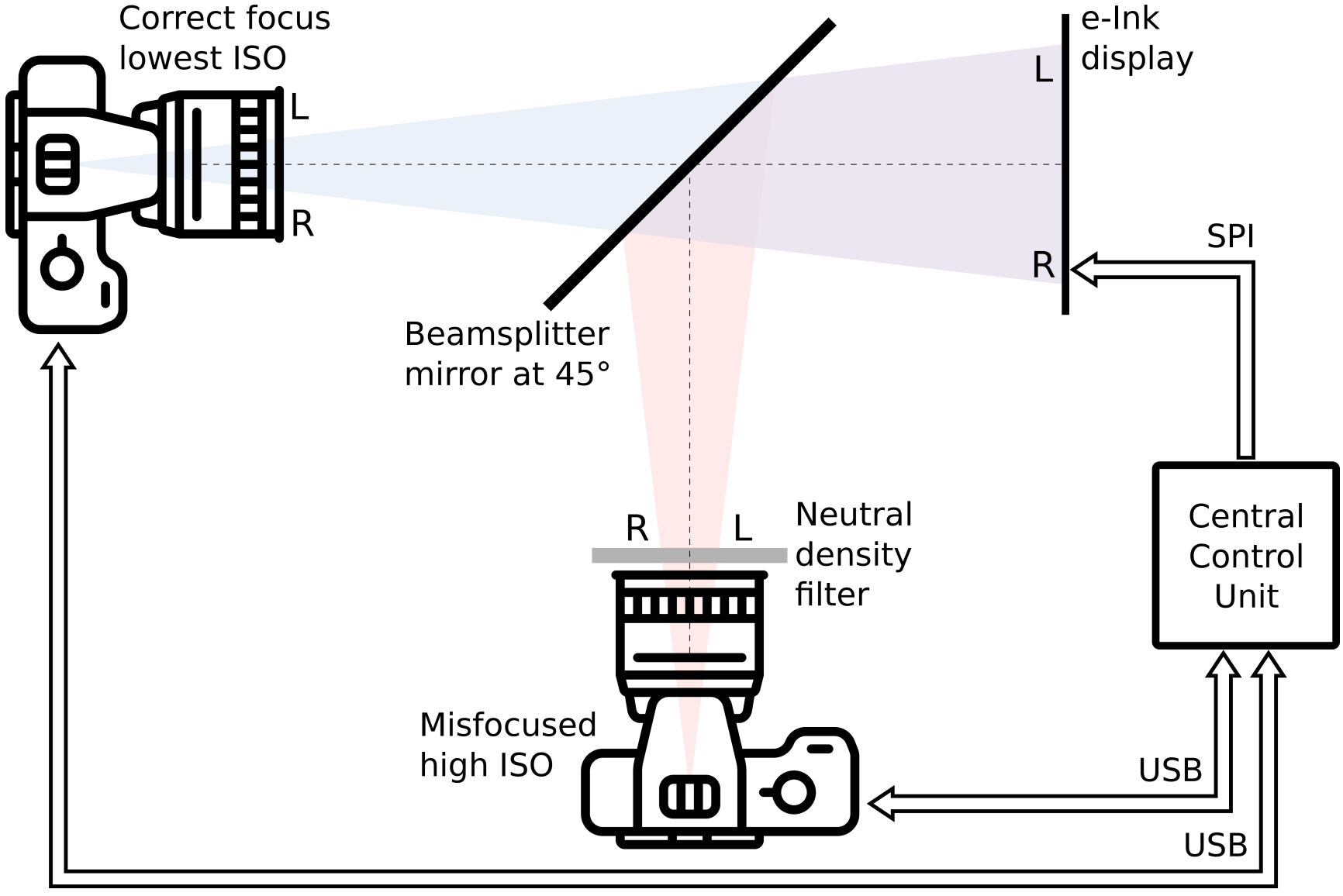
TV-menetelmän parannus TGV vähentää värien häiritsevää porrastumista

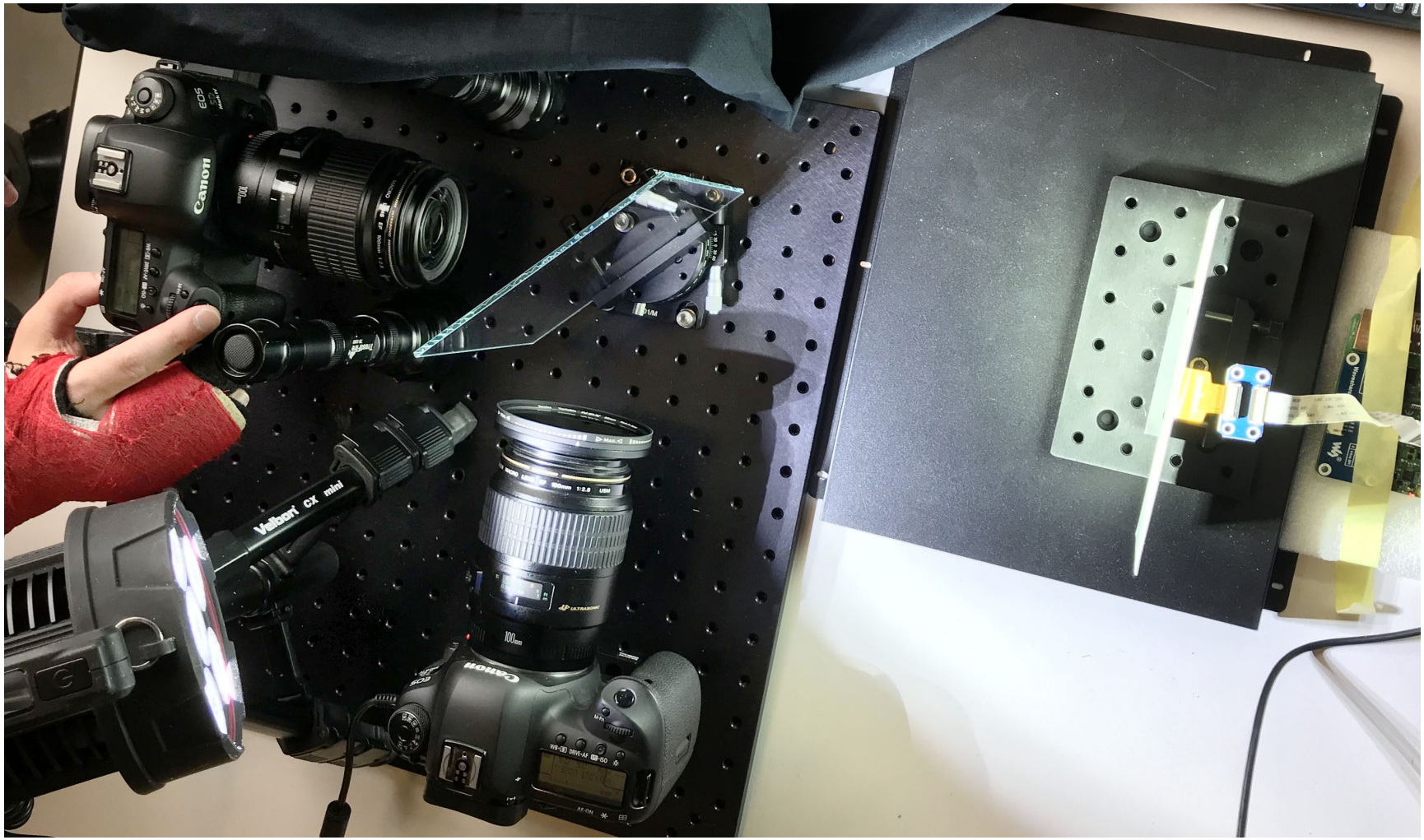
Kiitokset professori Kristian Brediesille TGV-koodin jakamisesta!

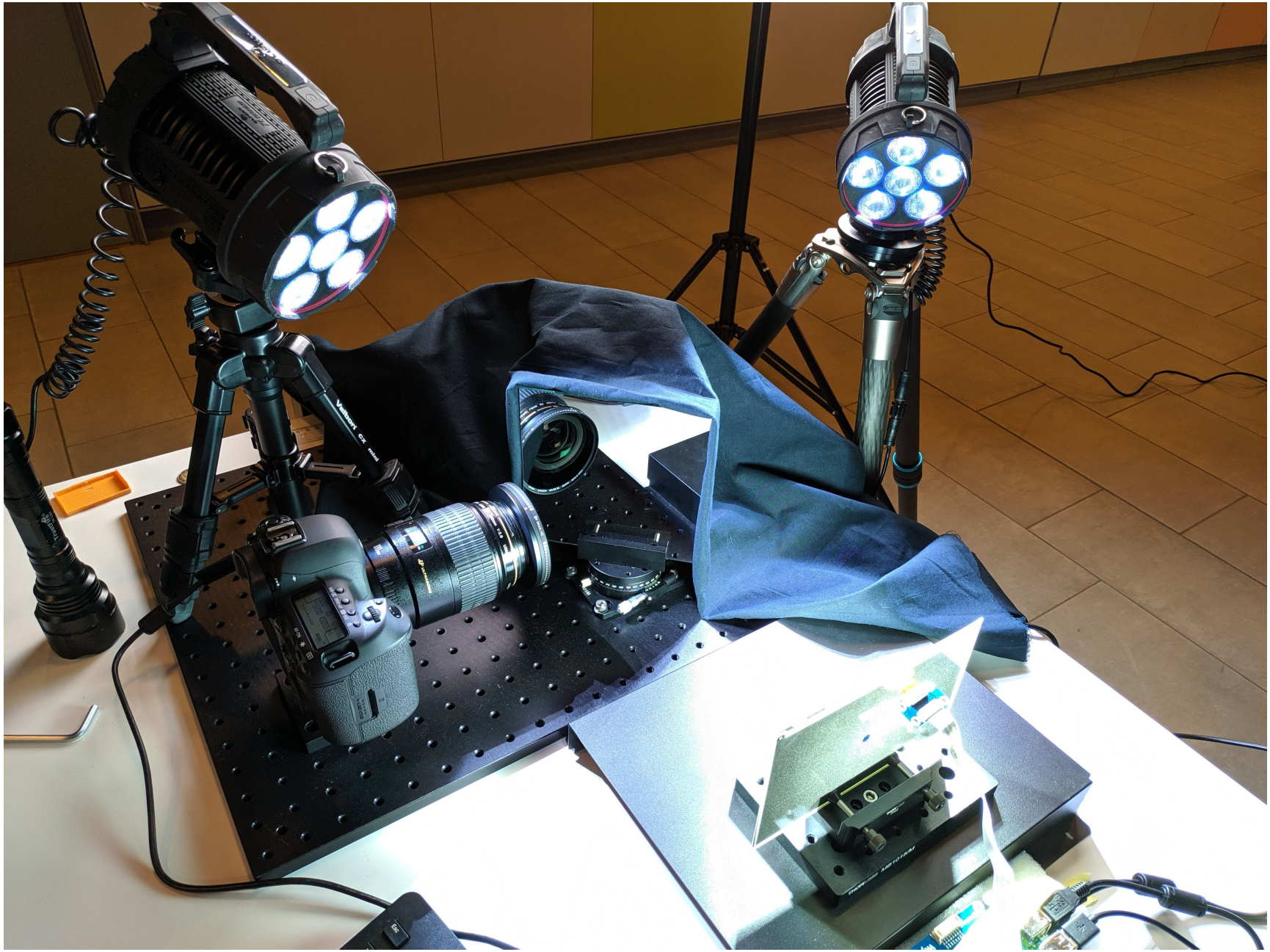
Viimeisintä huutoa oleva kaupallinen tekoälysofta tekee tällaista jälkeä

Kehitimme tutkimusryhmäni kanssa kuvien tarkennuskilpailun

Tässä mittalaitteemme




Canon
EOS
Vaiboon CX mini
ULTRASONIC
100mm
Canon




OV0Xq3AQ7D
WWHWsdeNKB
NHZYKdLoBr

Otimme kuvapareja yhä huonommin tarkennettuna

	xN5f3T378	
STEP 7	4fdJF e8SV qdsNku2pW4 WLPYRZ5nCf	
STEP 9	yK4pjYyPQe xkvumuQDPW wmHjrN EqE	
STEP 11	pvVpT8h Z W27uJ4dQfu ETNN8rTZhb	
STEP 13	tuqxjiYzk8 FFkyG4Fsvg DybTjdhVK4	

ETNN8rTZhb

STEP 13

tuqxjiYzk8
FFkyG4Fsvg
DybTjdhVK4

STEP 15

CsbakHQwDx
fQnJYAwXSL
MGRj84LXKs

STEP 17

rN2P Ayjz
zwJpcRRmdF
FmUTjEcwwP

STEP 19

BcsWr xNEn
kR3DMmvqTN
nB5Kk25jBT

Tulokset

Team	step 0	step 1	step 2	step 3	step 4	step 5	step 6	step 7	step 8	step 9	st
15_A	95.62	95.30	94.83	94.75	94.53	97.03	94.03	96.25	93.12	95.80	9
15_B	95.97	94.40	94.45	95.53	94.53	97.78	95.55	96.40	94.33	95.70	9
12_A	95.95	94.80	94.90	96.03	94.78	95.95	92.85	92.83	91.15	91.72	9
12_B	95.65	95.08	95.40	95.62	94.75	96.50	92.62	93.80	92.62	91.97	8
01	96.28	95.22	95.40	96.28	94.92	96.12	91.75	93.28	91.65	91.75	8
11_A	94.90	95.25	90.70	93.03	37.33	88.40	77.28	82.00	73.62	65.30	4
11_B	88.67	81.38	80.80	88.20	91.03	90.25	84.30	80.08	77.55	76.35	7
11_C	93.15	90.28	92.60	93.67	92.22	94.65	87.78	85.67	81.25	79.85	7
06	96.28	95.28	95.50	96.30	96.40	97.03	94.33	91.97	85.92	73.80	7
13	95.42	93.80	93.92	89.67	91.45	92.12	71.12	80.90	67.12	63.85	5
16_A	94.53	93.78	92.05	92.35	76.90	84.65	46.02	69.12	64.45	58.27	3
16_B	95.10	95.65	96.15	93.60	90.20	88.38	76.45	65.53	68.35	19.27	4
04	95.53	94.97	94.03	91.40	82.45	76.83	68	66.30	62.85	39.55	2
09_A	95.53	94.22	94.22	69.03	16.40	9.65	6.83	1.55	6.05	3.70	1
09_B	95.50	94.60	93.65	63.42	16.15	12.38	6.33	2.55	2.27	3.42	2

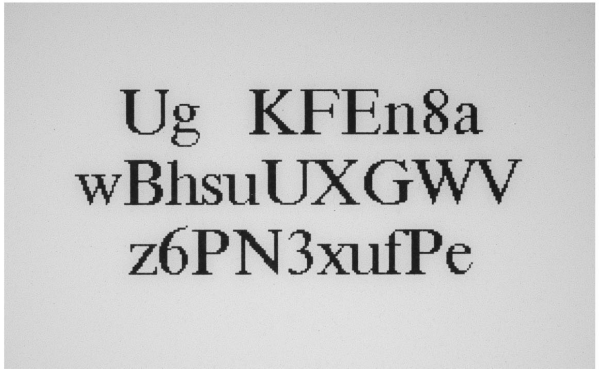
* Following the rules in case of category tie, the one with the highest

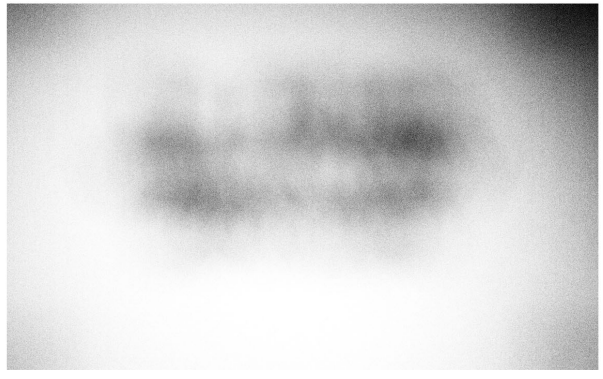
Tulokset

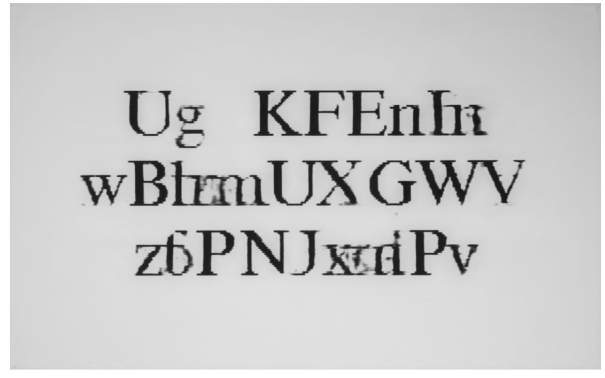
step 10	step 11	step 12	step 13	step 14	step 15	step 16	step 17	step 18	step 19	stop
93.75	91.55	91.42	92.00	87.15	77.50	89.00	81.97	80.85	71.65	19
92.97	92.80	91.65	93.22	86.28	73.60	89.50	81.35	79.97	69.88	
90.20	86.72	87.58	83.03	81.17	78.50	62.73	53.60	53.12	28.65	
85.80	83.50	85.95	85.72	82.97	84.15	77.80	72.33	71.80	61.38	18
88.67	88.83	87.12	87.55	84.88	18.02	82.47	70.30	71.00	67.17	14
42.90	52.75	3.50	0.00	43.88	6.42	0.00	1.93	2.23	0.68	
72.62	67.25	68.60	61.95	62.35	46.92	41.40	36.00	32.23	25.95	
79.15	67.08	62.80	60.83	54.23	32.60	36.35	23.05	21.88	21.75	10*
70.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10*
54.38	55.00	64.83	65.47	52.35	20.15	25.68	14.22	6.58	4.67	07
35.83	29.45	19.20	17.45	9.05	5.55	1.50	0.00	0.00	0.00	
4.03	13.50	7.42	3.80	2.48	0.00	0.00	0.00	0.00	0.00	06
24.38	13.82	10.70	5.95	3.30	1.43	0.00	0.00	0.00	0.00	05
1.70	3.05	1.62	1.55	0.33	2.90	2.85	3.73	7.62	3.62	
2.62	1.52	4.03	5.55	1.27	2.92	2.20	1.95	5.83	2.42	02

st percentage in the stop category wins.

Voittajajoukkueen tyylinäyte tasolla 19



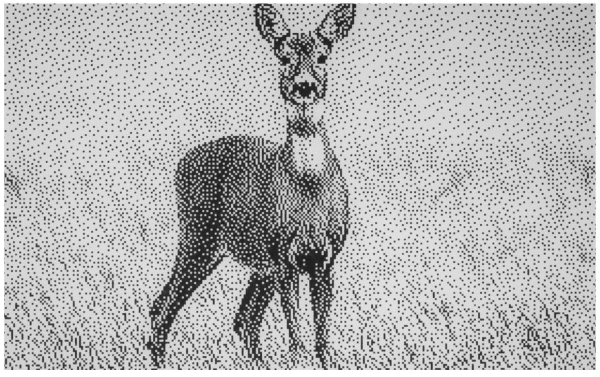


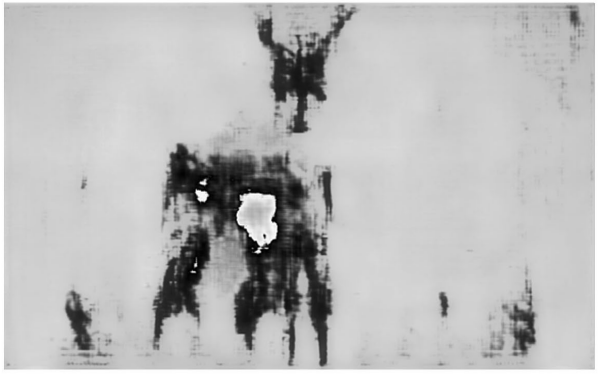


Results of HDC2021

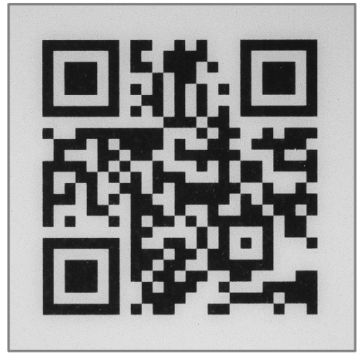
- 1st place: Theophil Trippe, Jan Macdonald & Maximilian März from TU Berlin and Martin Genzel from Utrecht University.
- 2nd place: Ji Li, Department of Mathematics, National University of Singapore.
- 3rd place: Daniël M. Pelt, LIACS, Leiden University, Leiden, The Netherlands.

Testikuvakin onnistui voittajilta

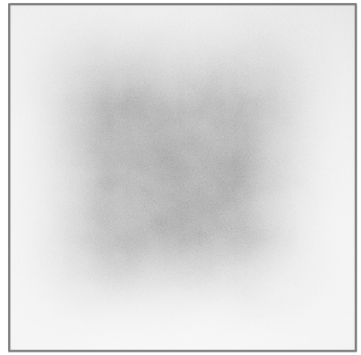




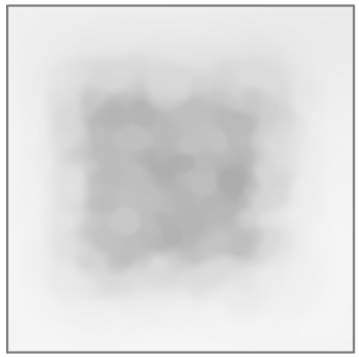
Ground truth

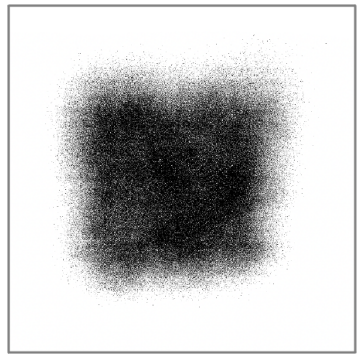


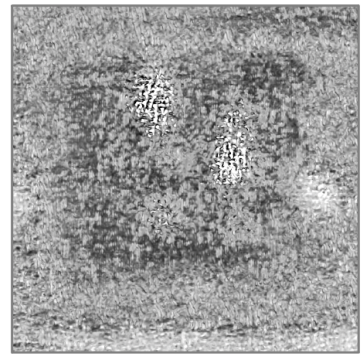
Blurred data

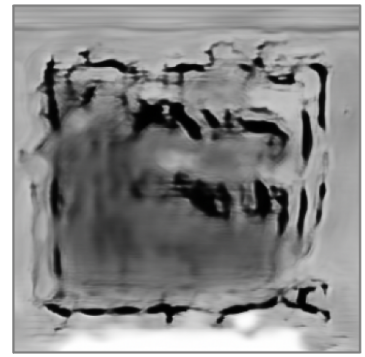


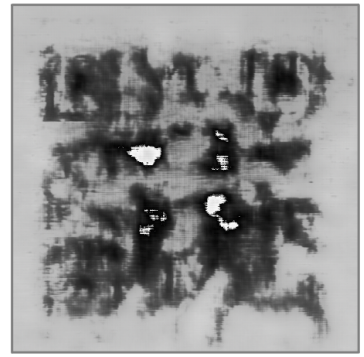
Reconstructions by Helsinki Deblur Challenge 2021 participants

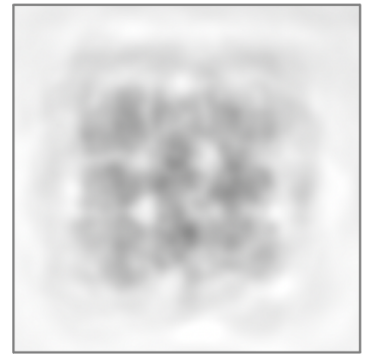












Thank you for your attention!

←—Slime mold called Lycogala conicum


Thank you for your attention!